Second Quarterly Progress Report

DEVELOPMENT OF THERMIONIC CONVERTERS

Prepared for
California Institute of Technology
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Contract 952255

EOS Report 4018-Q-2 15 July 1969

ELECTRO-OPTICAL SYSTEMS
A XEROX COMPANY
PASADENA, CALIFORNIA 91107 • 213/351-2351

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Prepared by
Dean Jacobson
Randy Hamerdinger

Approved by

A. O. Jensen, Vice President and Manager
Advanced Technologies Division

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SECTION 1

INTRODUCTION

This is the second quarterly progress report under JPL Contract 952255. It is a 20-month program to design and develop low-power, high-efficiency thermionic converters of cylindrical geometry. The converters will be capable of being integrated to form a modular power supply. The central philosophy of this approach is to increase the reliability of thermionic space power supplies by redundancy of the basic component.

Seven converters and a bombardment heater unit are deliverable items per the contract Statement of Work. The converter development is to proceed in an iterative fashion whereby each converter design is reviewed separately and approved by JPL before fabrication. Subsequent performance data are reviewed separately, and will formulate the basis for redesign.

SECTION 2

CONVERTER SC-2

2.1 DESIGN AND FABRICATION

Converter SC-2 has the same design parameters as SC-1; i.e., a power density of 4 watts/cm^2 at 0.7V at an emitter temperature of 1400°C.

The refinements of SC-2 which were predicated upon the performance of SC-1 have been discussed in detail in EOS Report 4018-Q-1. The fabrication procedures followed on SC-2 were the same as those reported for SC-1.

2.2 PERFORMANCE TEST

Converter SC-2 is currently on test. Results have been obtained at emitter temperatures of 1300°C, 1400°C, and 1500°C.

Figure 1 is a current optimization curve at a constant voltage of 0.2V, an emitter temperature of 1300°C, and a collector temperature of 730°C. The optimum cesium reservoir temperature is 298°C at a current of 47.8 amps.

Figure 2 is a current optimization curve at a constant voltage of 0.4V at an emitter temperature of 1300°C and a collector temperature of 648°C. The optimum cesium reservoir temperature is 272°C at a current of 9.9 amps.

In Fig. 3, at a constant voltage of 0.6V the optimum cesium reservoir temperature is 254°C with a current of 1.34 amps. The emitter temperature was 1300°C and the collector was 630°C.

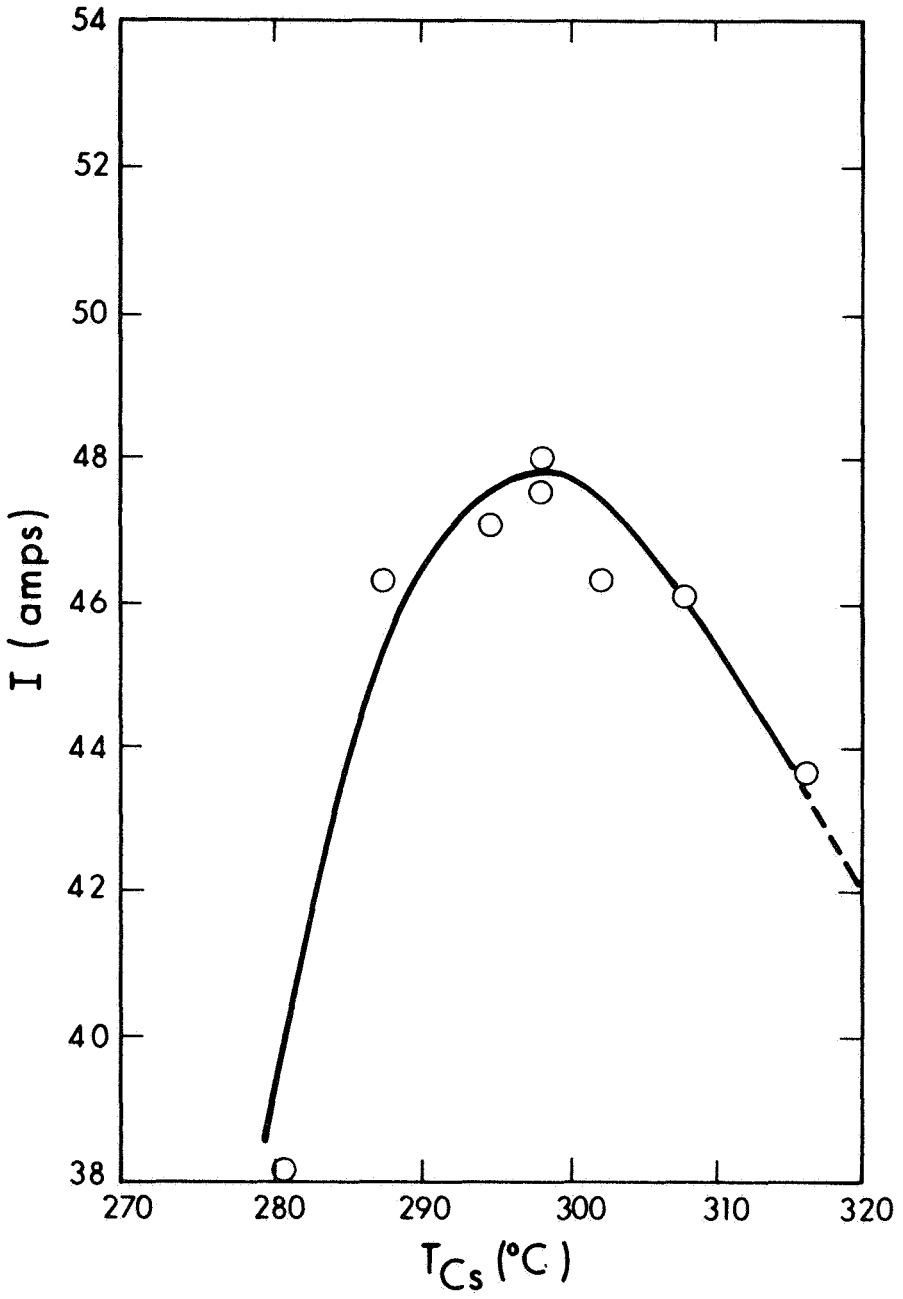

Figure 1. Current Optimization Plot For SC-2 Taken at T_E = 1300°C, T_C = 730°C and a Constant Voltage of 0.2 Volts

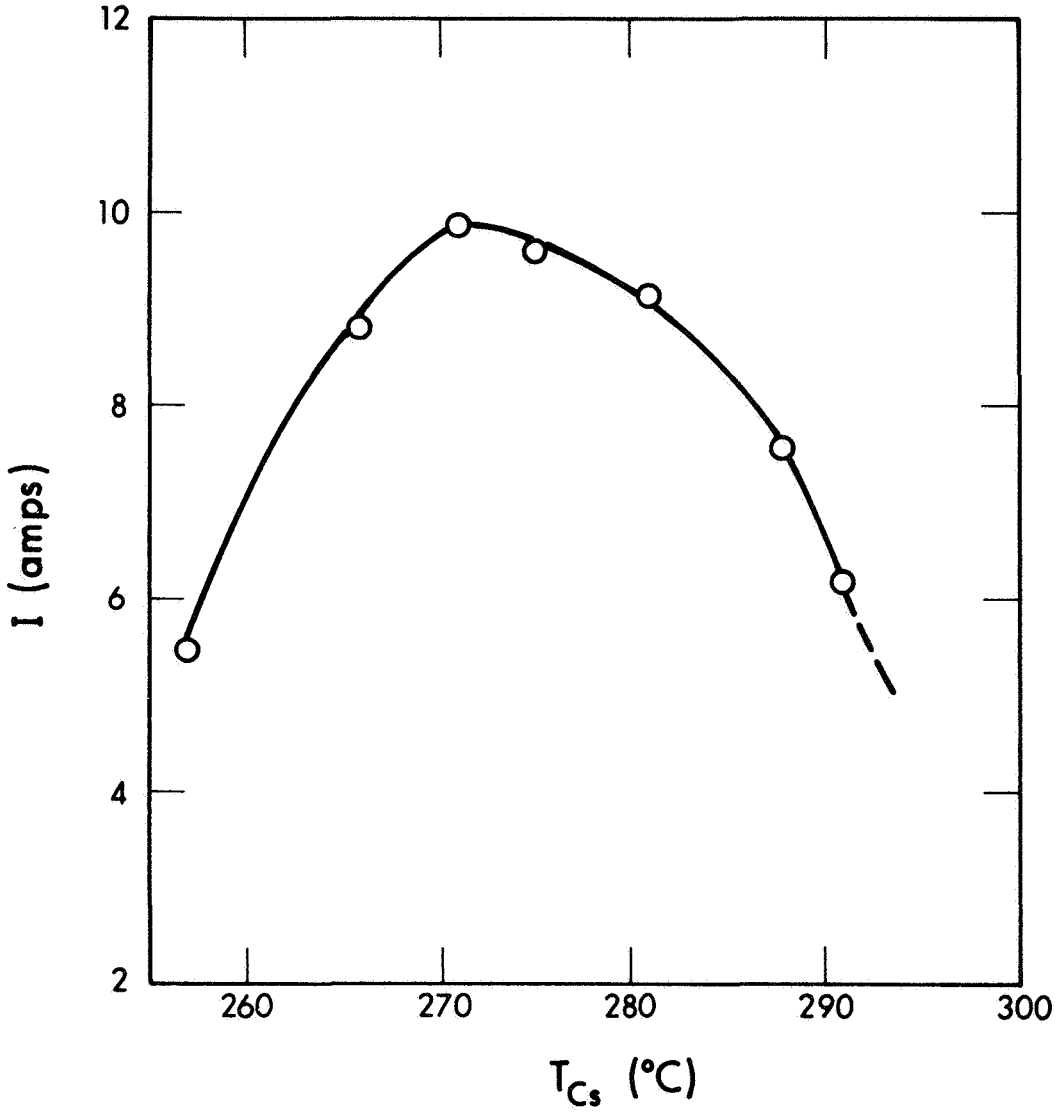

Figure 2. Current Optimization Plot For SC-2 Taken at T_E = 1300°C, T_C = 648°C and a Constant Voltage of 0.4 Volts

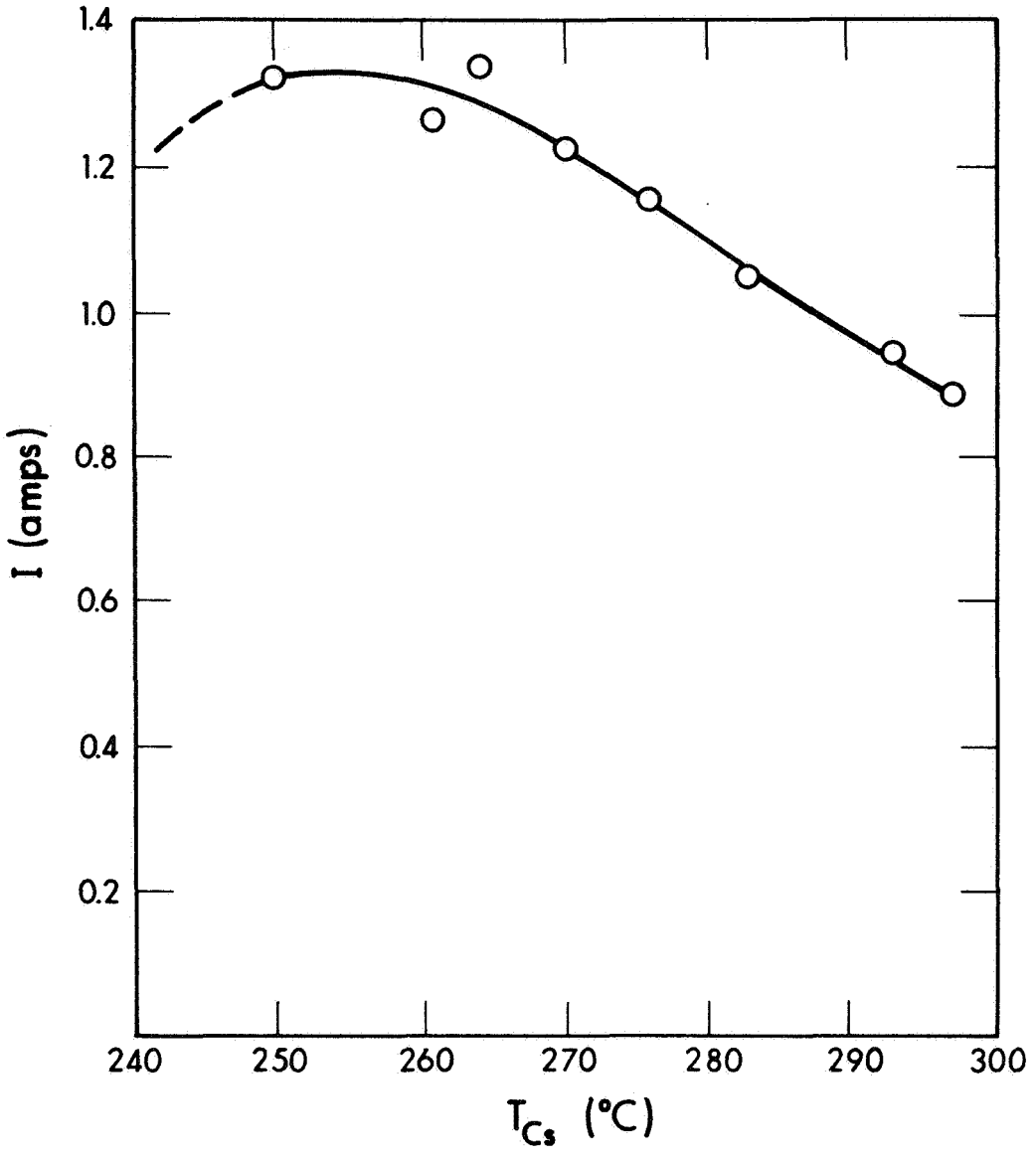

Figure 3. Current Optimization Plot For SC-2 Taken at T_E = 1300°C, T_C = 630°C and a Constant Voltage of 0.6 Volts

Figure 4 is a performance plot for SC-2 at an emitter temperature of 1300°. The data at voltages above 0.5V are not truly optimum because it was impossible to obtain the high collector temperatures required. The device was designed and built to operate at 1400°C with a current of 45 amps.

At an emitter temperature of 1400°C optimizations were performed at 0.4V and 0.5V. In Fig. 5, at 0.4V the optimum cesium reservoir temperature was found to be 299°C with a current of 44.8 amps. The collector temperature was 730°C.

At a constant voltage of 0.5V, the cesium reservoir temperature was found to be 294°C with a current of 33.9 amps as shown in Fig. 6.

Figure 7 is a performance plot for SC-2 at an emitter temperature of 1400°C.

As shown in Fig. 7, at 0.5V, a current of 34 amps was obtained at 1400°C. The power density is therefore 4.25 watts/cm^2.

In Figure 7, data at 0.3, 0.4, 0.5, and 0.6V was taken under steady state D.C. conditions. After this data was taken, the emitter-envelope weld opened up. The failure appeared to be due to thermally induced stresses in the envelope. The condition was aggravated by the bombardment of the envelope by the gun shields as illustrated in Fig. 9 of EOS Report 4018-Q-1.

A feasibility weld was performed with the welding parameters used on the device. The resulting cross-section of the weld shown in the Appendix indicates that the weld was reliable for normal operating conditions.

The device was cleaned with distilled water and alcohol by driving the fluids through the emitter-envelope leak and out the opened cesium reservoir. The envelope was then rewelded to the emitter and the device was processed and loaded with cesium in the usual manner.

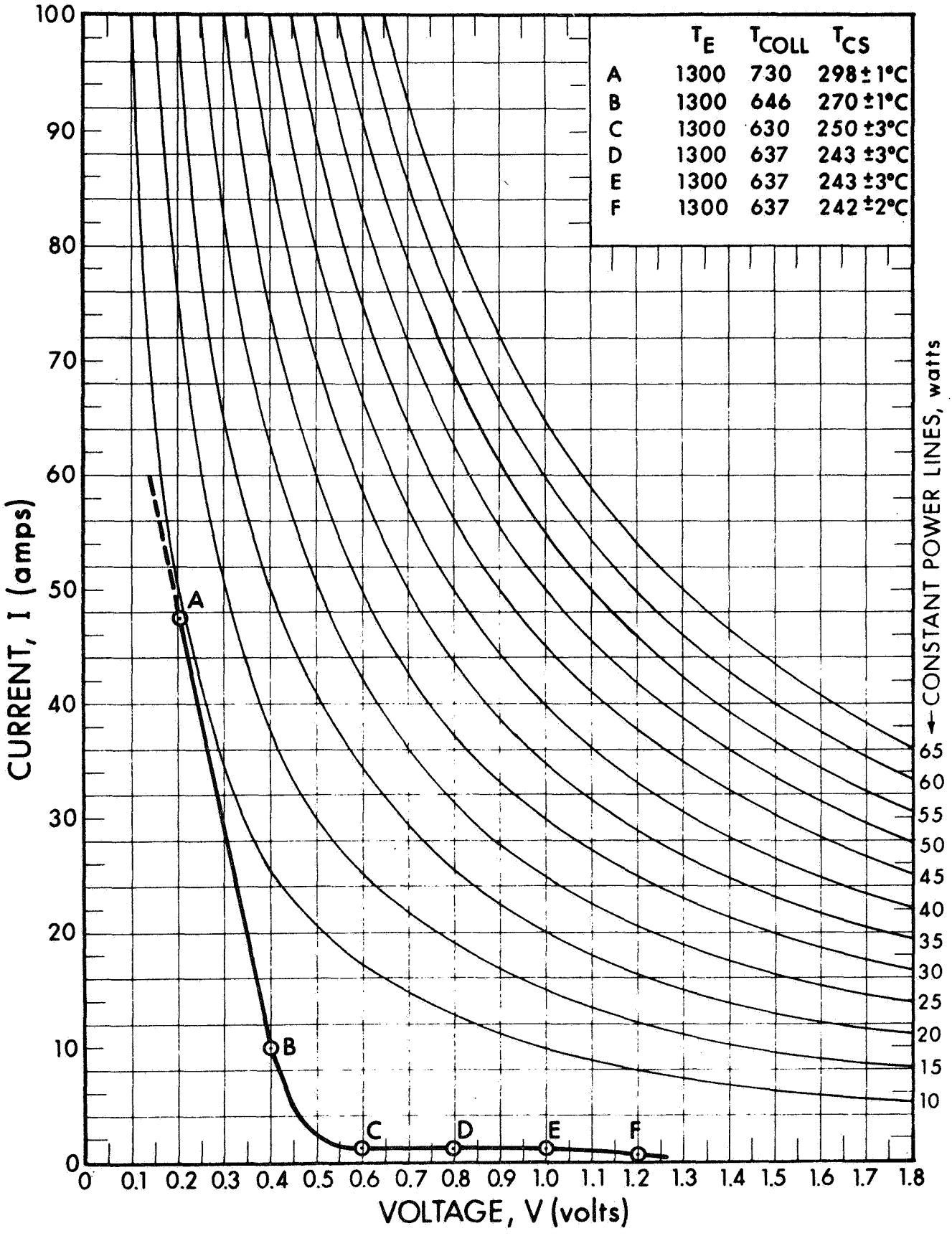

Figure 4. Performance Plot For SC-2 at T_E = 1300°C

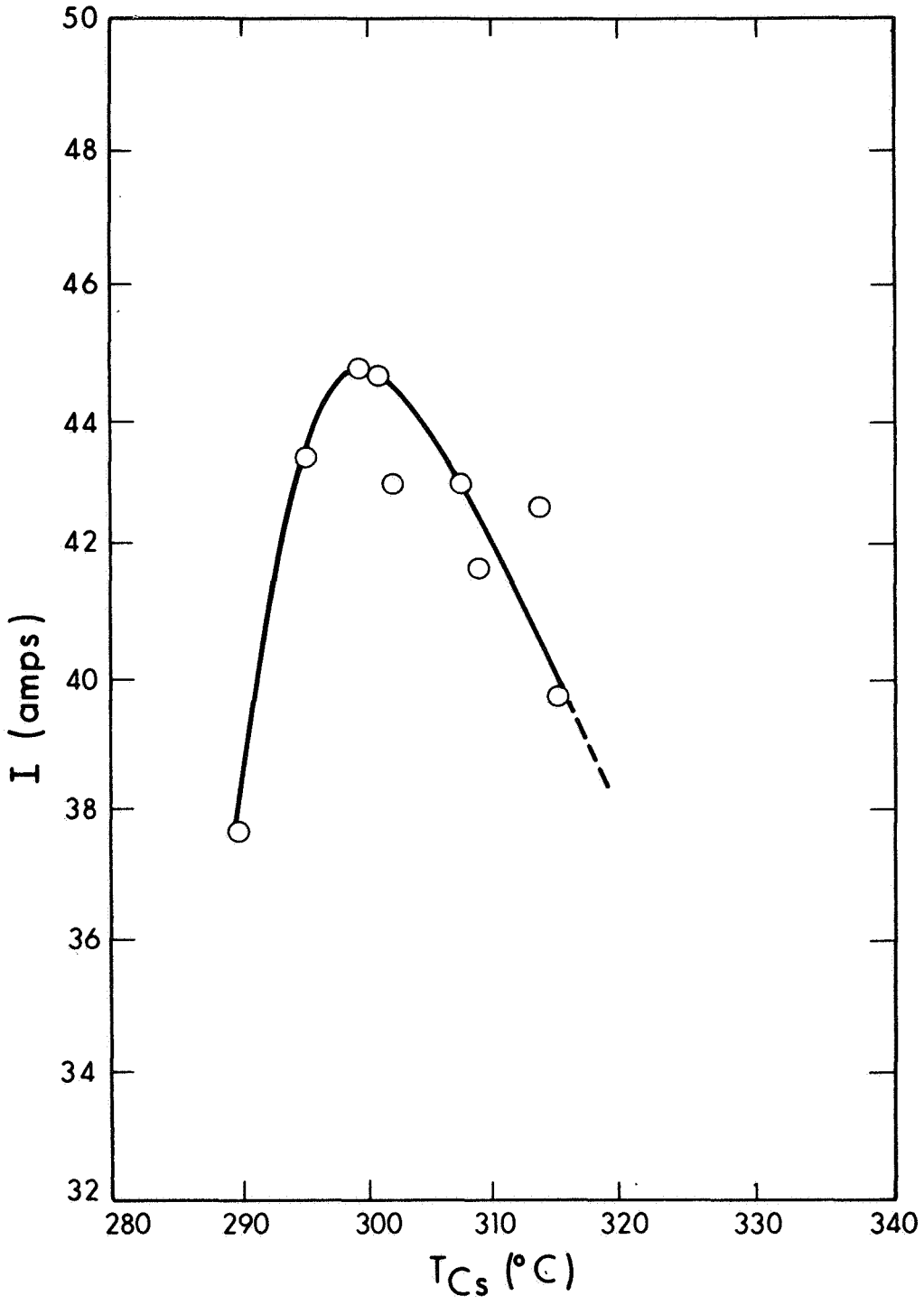

Figure 5. Current Optimization Plot For SC-2 at T_E = 1400°C and T_C = 730°C at a Constant Voltage of 0.4 Volts

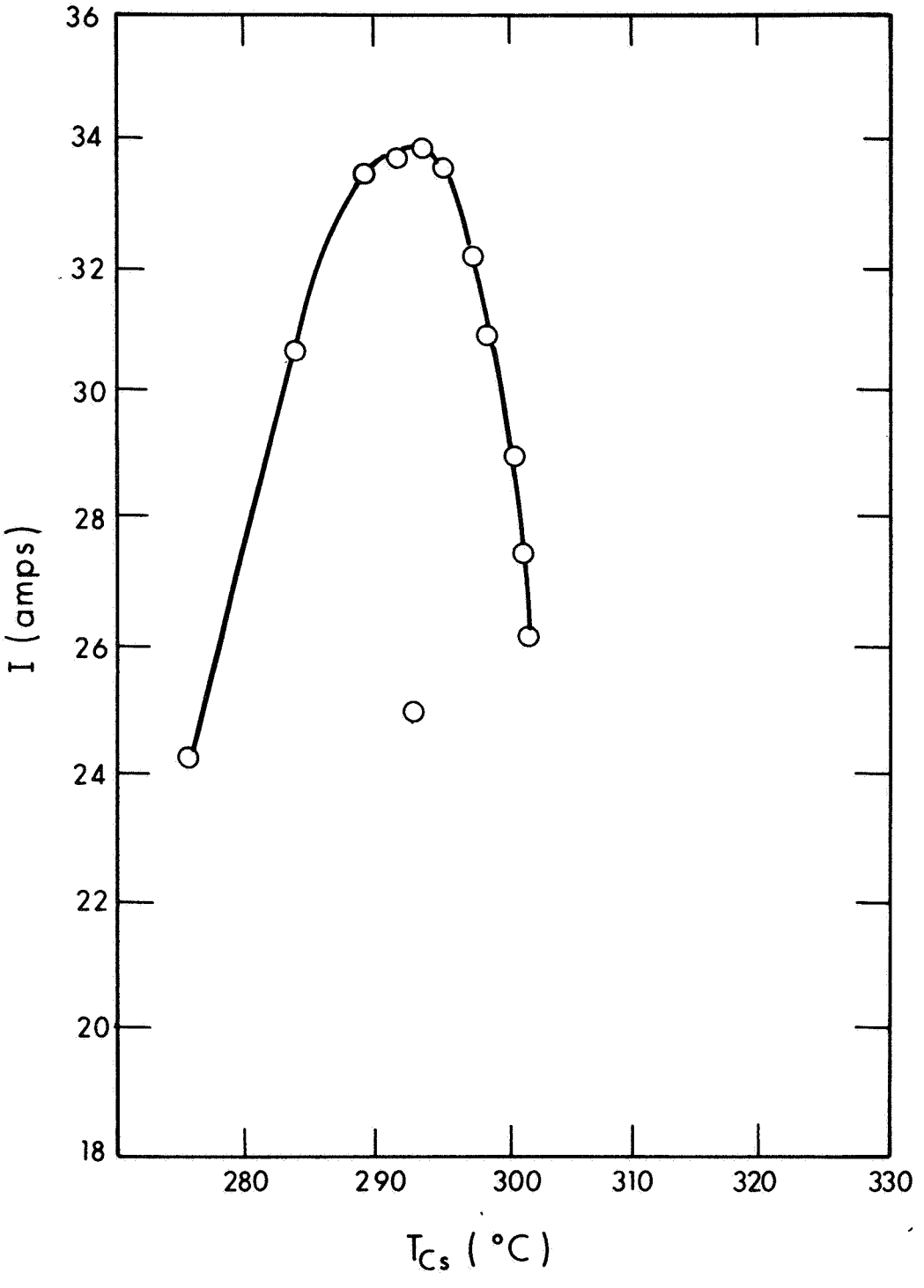

Figure 6. Current Optimization For SC-2 at T_E = 1400°C and T_C = 685°C at a Constant Voltage of 0.5 Volts

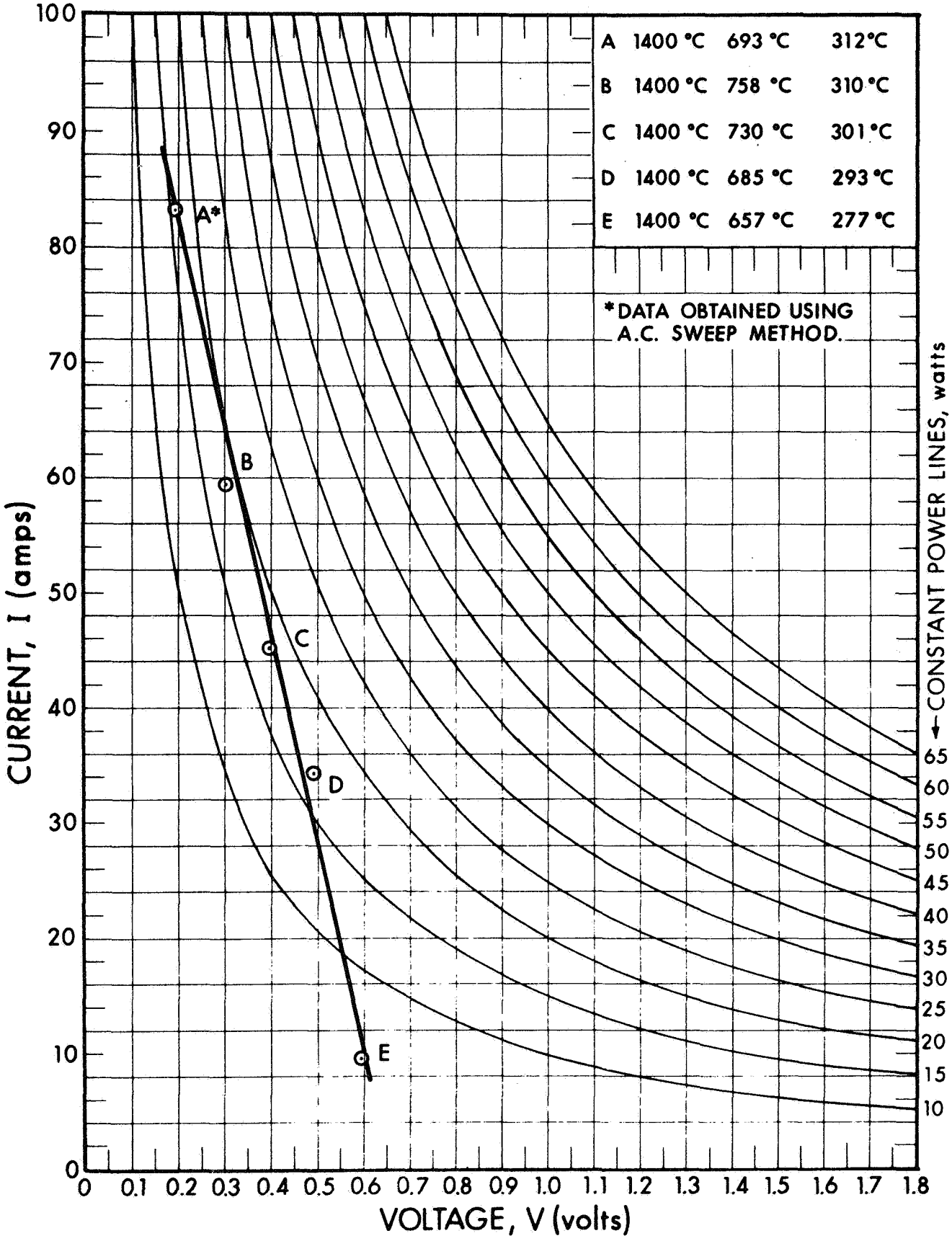

Figure 7. Performance Plot For SC-2 at T_E = 1400°C

Upon testing the device it was found that the 1300°C data could be reproduced. At 1400°C and above, it was extremely difficult to reproduce data due to apparent emitter-collector shorting. Apparently the second welding created a certain misalignment of the emitter with respect to collector. This manifested itself as shorts at elevated temperatures. One method used in an attempt to realign the emitter was to take it to a high temperature (1700°C). This operation permitted reproduction of various 1400°C data. At 1500°C the criticality of the temperature on shorting allowed only A.C. data to be taken.

Figure 8 is a current-voltage A.C. sweep oscillograph. The emitter temperature was 1500°C, the collector temperature was 768°C. The cesium reservoir temperature was 323°C. From this information, the performance plot, Fig. 9, was generated.

Figure 10 is a current-voltage A.C. sweep oscillograph at a cesium reservoir temperature of 305°C and a collector temperature of 733°C. The performance plot, Fig. 9, shows the optimum data from Fig. 10 at 0.35V and a current of 56 amps. This is a power density of 4.9 watts per square centimeter. The converter is on test at the present time, and attempts are being made to make further improvements in the performance.

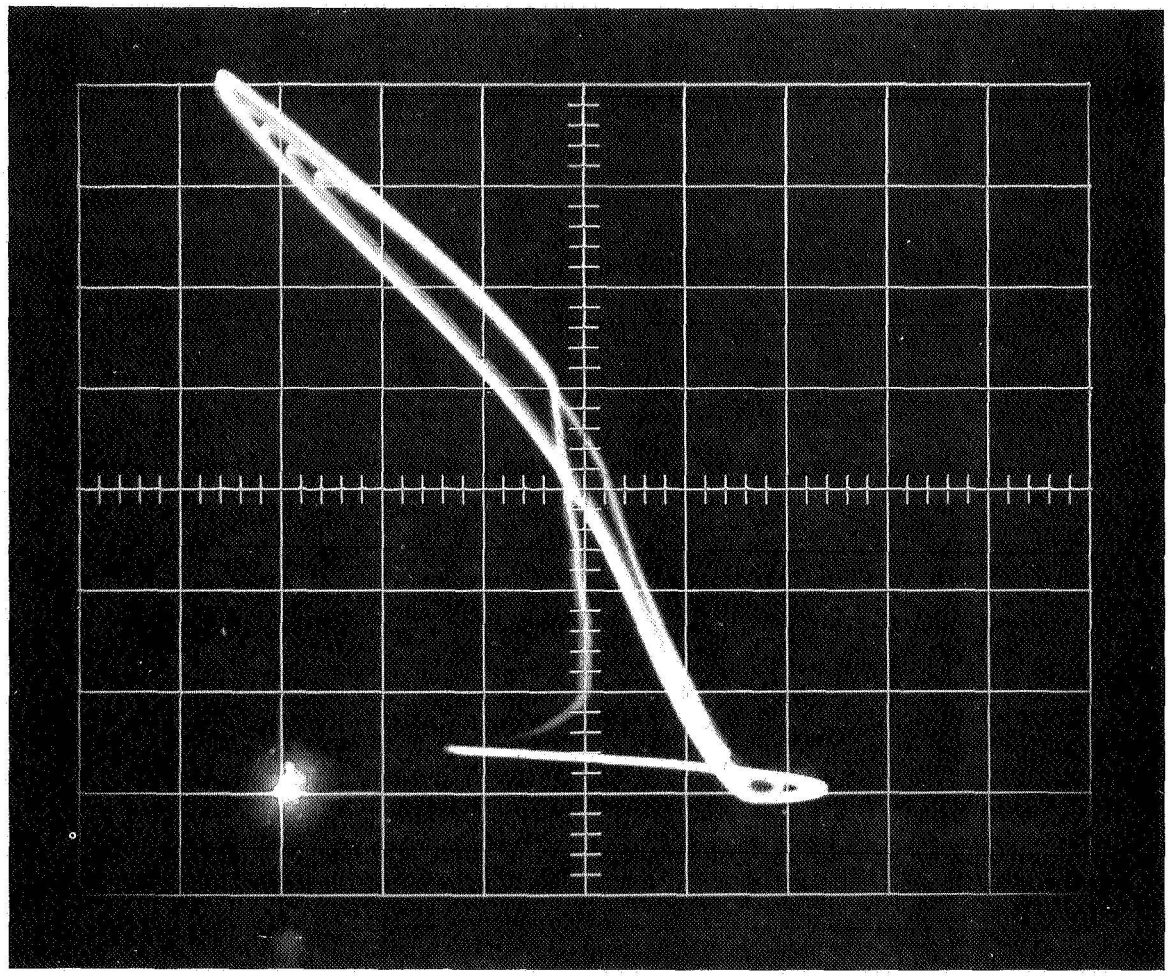

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Figure 8. Oscillograph from SC-2 at T_E = 1500°C and T_C = 768°C at T_{CS} = 323°C.
Scale: 0.1 volts/division, 20 amps/division.

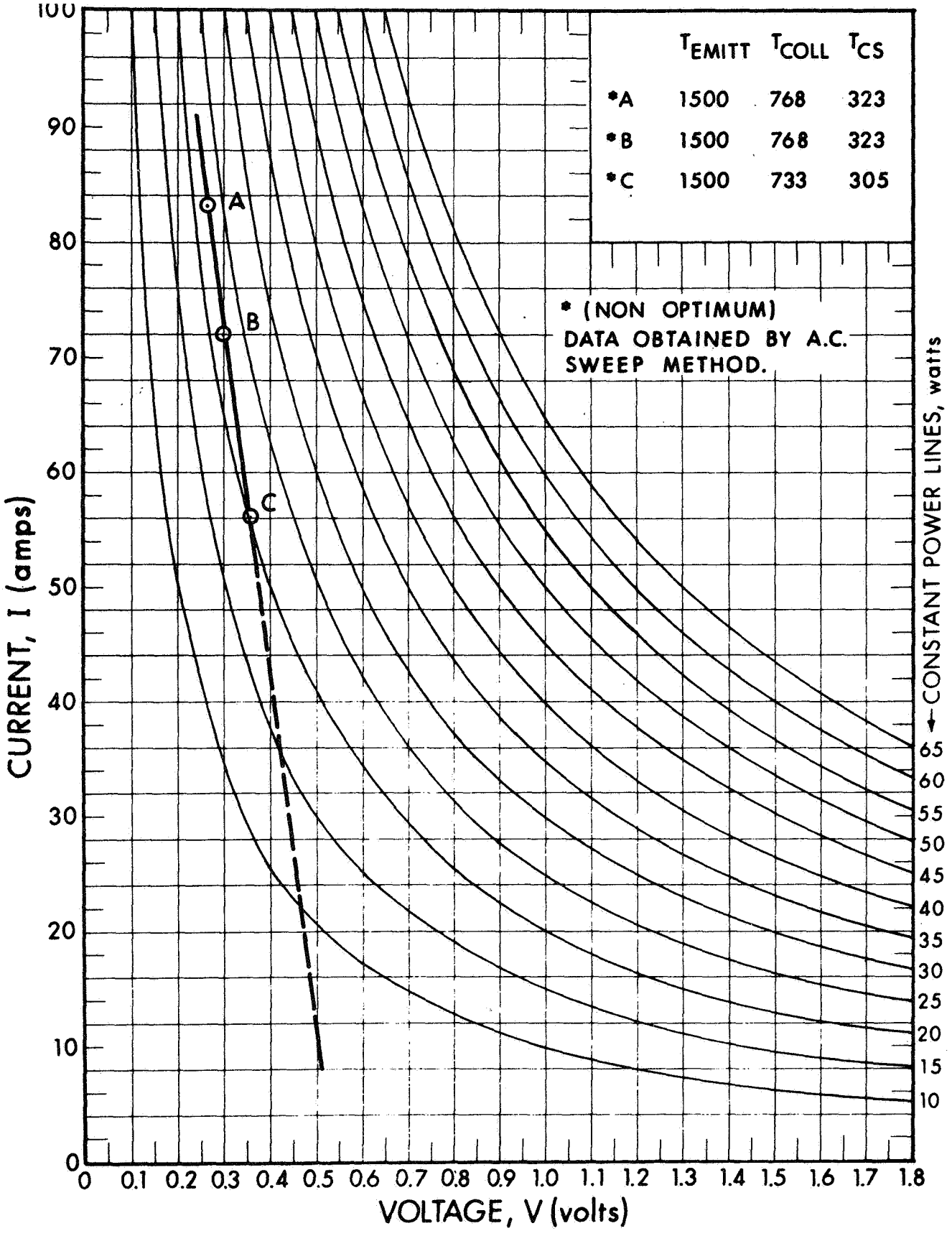

Figure 9. Performance Plot For SC-2 at T_E = 1500°C

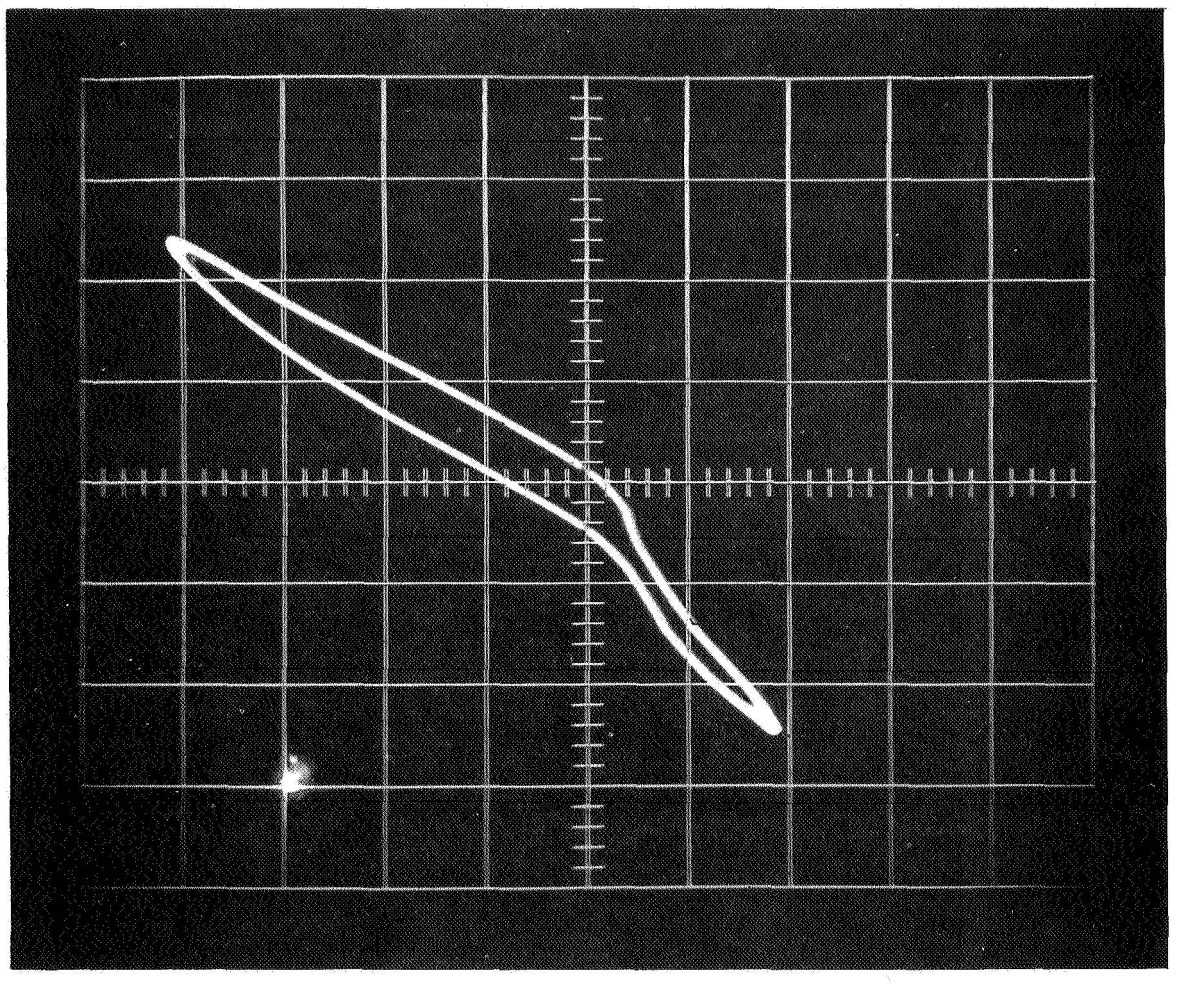

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Figure 10. Oscillograph from SC-2 at T_E = 1500°C and T_C = 733°C at T_{CS} = 305°C.
Scale: 0.1 volt/division, 20 amps/division.

APPENDIX

Figure 11 is a photomicrograph of a feasibility weld of a rhenium envelope to a cylindrical rhenium emitter. The magnification is 150X. The penetration of the weld is approximately 0.017 in. The small grain size provides good strength and reliability.

The weld parameters were as follows:

Filament current	=	1.75 (amperes)
Accelerating voltage	=	150 (kV)
Beam current	=	3.4 (mA)

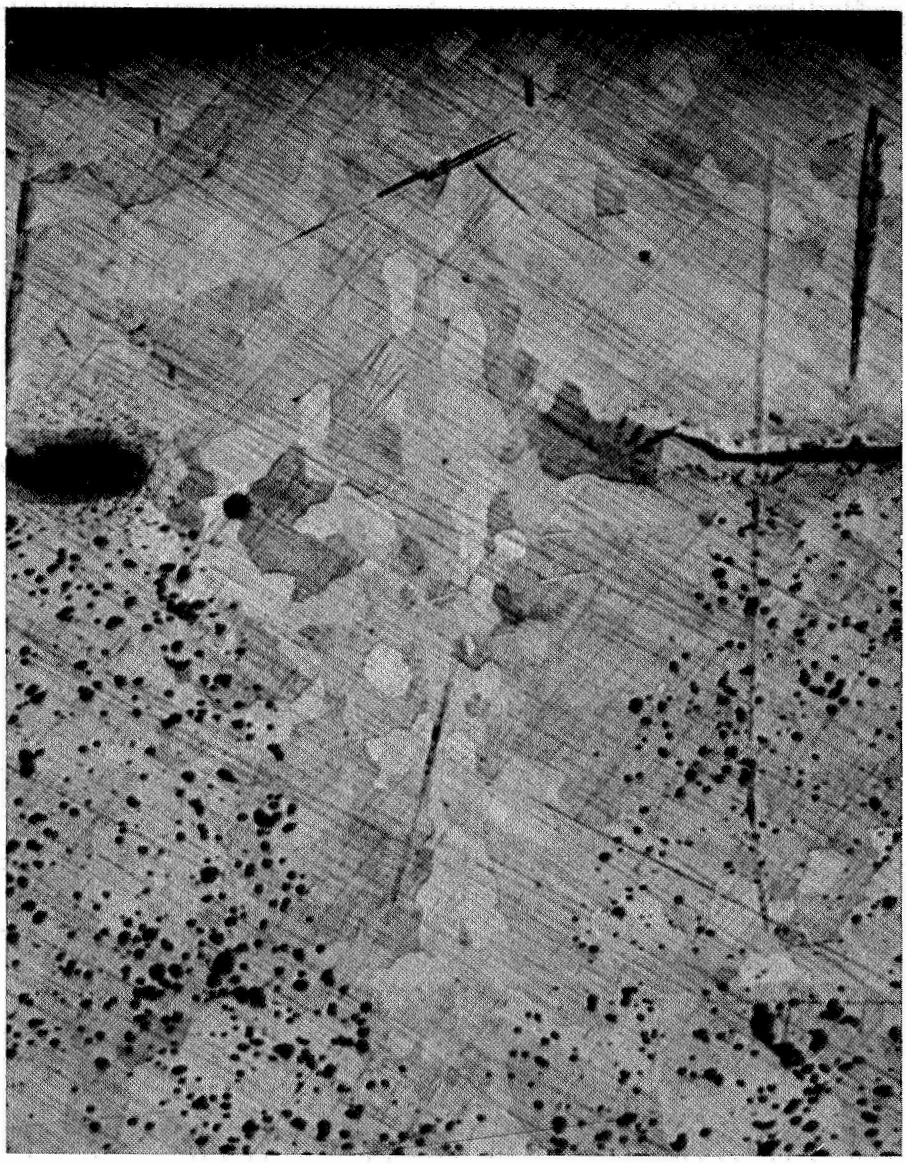

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Figure 11. Photomicrograph of Reenvelope - Reemitter Electron Beam Weld on Feasibility Samples. Magnification — 150X.